Competition and Efficiency in the U.S. Launch Vehicle Market

To what extent has the U.S. launch vehicle market become more allocatively and productively efficient as a result of increased competition?

Table of Contents

Introduction

As it began retiring the Space Shuttle, the National Aeronautics and Space Administration (NASA) saw the need to turn to the free market for its crew-and-cargo-launching needs. It began investing in private launch vehicle companies using its Commercial Crew and Cargo Program (C3PO) to manage its Commercial Orbital Transportation Services (COTS) partnership agreements. The objective is to "Create a market environment in which commercial space transportation services are available to Government and private sector customers"[1]. This program includes giving contracts to private launch vehicle companies to give them sufficient resources to develop safe and cost-effective launch vehicles. The C3PO helped kick-start the era of private launch vehicle competition in the United States. The question I will address in this paper is how the resulting increased competition in the U.S. launch vehicle market affected its productive and allocative efficiency, especially when compared with other factors.

Definitions & Guidelines

The “US launch vehicle market” includes any corporation based in the United States that is a Launch Service Provider (LSP, i.e. a company which launches rockets) and/or is a supplier to LSPs. A notable inclusion is Rocket Lab, which, at first glance, may appear to be a company based in New Zealand, but it is actually “an American company with headquarters in Los Angeles and a wholly-owned New Zealand subsidiary”[2].

1 "Commercial Crew & Cargo." NASA. Accessed September 09, 2018. https://www.nasa.gov/offices/c3po/home/c3po_goal_objectives.html.

2 "Frequently Asked Questions." Rocket Lab. Accessed September 09, 2018. https://www.rocketlabusa.com/frequently-asked-questions/.

The market condition "allocative efficiency" used in the Research Question and throughout this essay is when the price (or marginal benefit) of the good (a rocket launch) is equal to the marginal cost of producing the good. Likewise, the market condition "productive efficiency" is defined as when the producer of a good is producing at level of output where their Average Total Cost is minimized.

Method

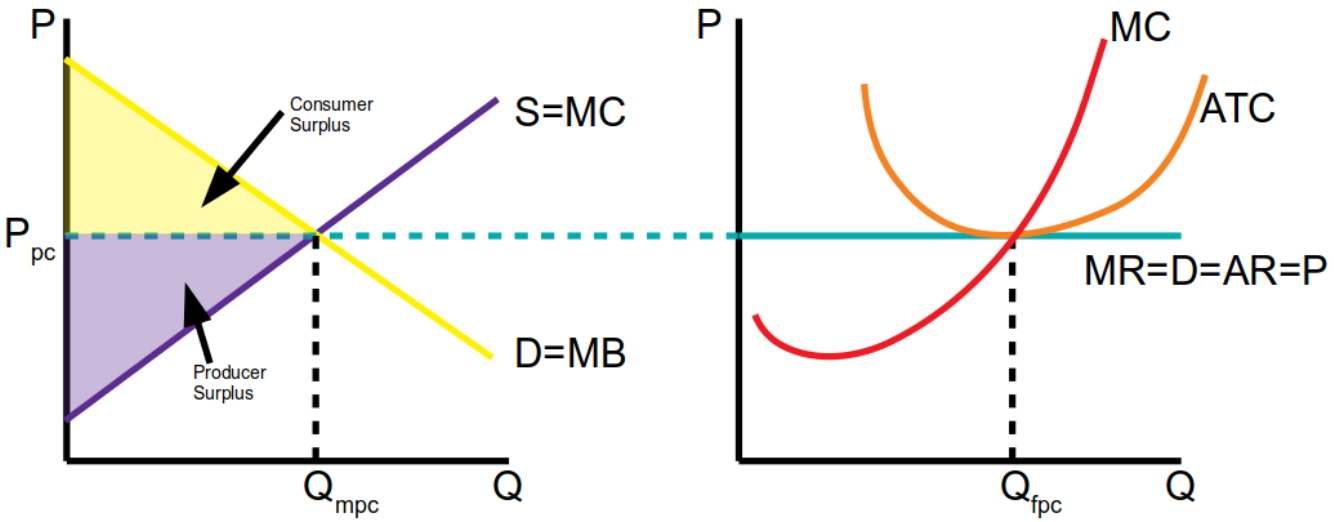
Historical rocket launch data was gathered from planet4589.org[3], a website run by Jonathan McDowell, a Cambridge-educated astrophysicist. The data was filtered to include only the US launch vehicle market. As many of the researched companies are private, and publish limited information, hard data for the costs of production, profit margins, and the costs of launch vehicles are often hard to find. Thus, news reports by reputable sources, press releases by companies, and government filings were used to analyze how the commercial and relative competitive positions of companies in this market have changed in the last five years. With these, it can be deduced how the efficiency in the market has changed.

3 McDowell, Jonathan. *Launchlog*. Txt. August 2018. http://planet4589.org/space/log/launchlog.txt

Economic Theory

To answer this research question, the effect of increased competition on the productive and allocative efficiency of a market must be analyzed.

Figure A: Market in Perfect Competition **Figure B: Firm in Perfect Competition**



As seen in Fig. A, a market in perfect competition achieves allocative efficiency, as the price and quantity produced are at the equilibrium point, where Supply (S) equals Demand (D). Furthermore, in Fig. B, the firm is producing at a quantity Q_{fpc} where Marginal Cost (MC) equals Marginal Revenue (MR), because of the profit maximization rule. As this is also the minimum of the Average Total Cost curve (ATC), the firm is productively efficient. The economic model of perfect competition relies on several assumptions—that there are no barriers to entry, that the companies produce an identical product, that there are very many firms, and that the costs of production are the same for all of the firms—which are not valid in the U.S. launch vehicle market.

Figure C: Market in Monopoly

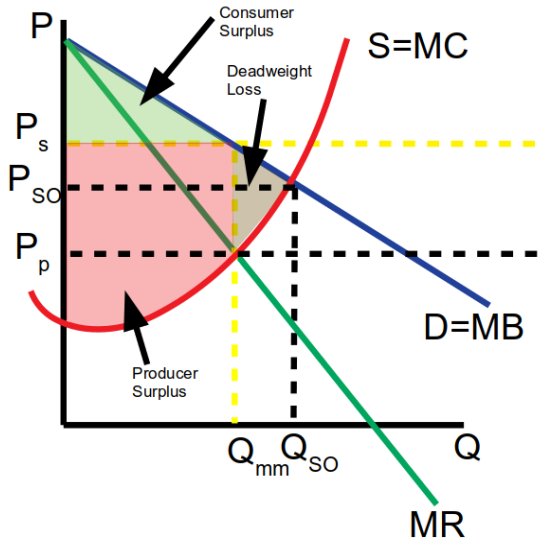
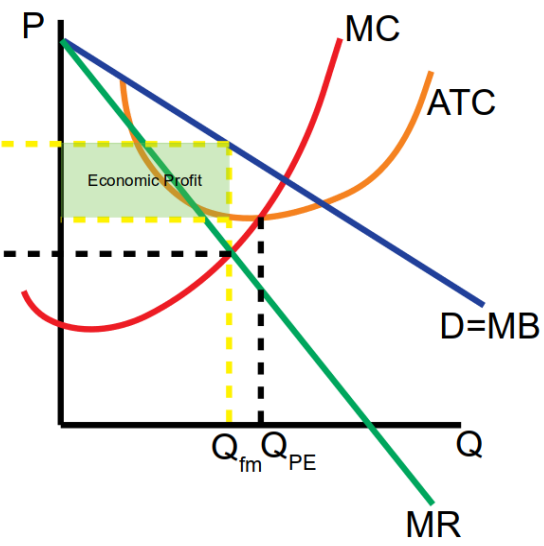


Figure D: Firm in Monopoly



As can be seen in Fig. C, a market in monopoly does not achieve allocative efficiency, as the amount and price are Q_{mm} and P_S, while the equilibrium point is at P_{SO} and Q_{SO}. As a result, social surplus, the sum of producer and consumer surplus, is not maximized and there is a dead-weight loss. In Fig. D, the firm is producing at a Q_{fm}, the quantity at the intersection of MC and MR (due to the profit maximization rule), which is fewer units than the quantity, Q_{PE}, that would be required to produce at the minimum of the ATC, making the firm productively inefficient. It is further evident that the firm is earning economic profits, due to the difference in the price of production (P_p) and sale (P_s). The economic model of monopoly can also not be directly applied to the U.S. launch vehicle market, as there is more than one firm in the market.

It can thus be inferred that the U.S. launch vehicle market lies somewhere between perfect competition and monopoly, in the realm of monopolistic competition and oligopoly. As shown above, freer market structures lead to more productive and allocative efficiency. Thus, changes in the market structure of the launch vehicle market can be analyzed to determine how productive and allocative efficiency have changed.

Analysis

The state of the market in 2013

Alan Stern, a former NASA associate administrator, stated that "[Defense department customers] *don't care* whether [the launch cost] is $100 million or $300 million; it's in the noise. What they want is a guarantee it's going to work."[4] Essentially, this means that the primary defense launch contractor at the time, United Launch Alliance (ULA)[5], was able to disregard efficiency. ULA's Atlas and Delta rockets have only experienced 49 failures in their history, out of 710 launches, a 93.1% success rate. The reason that ULA was the primary government contractor is this incredible long-standing success rate and the reputation it created[6]. Although SpaceX, at the time, had succeeded on 100% of its contracts, it was still seen as more risky as it was a new company and had not had the time to develop a good reputation. Thus, ULA's product differentiation (in the form of a historically high success rate), a characteristic of a market with oligopoly or monopolistic competition, was part of what gave them a significant market share.

In 2013, ULA had a monopoly on government contracts. Elon Musk stated that "[ULA's] incentive is to maximize the cost of a vehicle, right up to the threshold of cancellation."[7] The reason it had this incentive was that the government had used cost-plus contracts[8], where the government would pay for all of the costs of the launch, plus a mark-up. Hence, if a launch had a higher cost, ULA earned proportionally more economic profit. ULA does not release the prices of its rockets publicly and it is

4 Chaikin, Andrew. "Is SpaceX Changing the Rocket Equation?" Air & Space Magazine. January 01, 2012. Accessed September 10, 2018. https://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation

5 Delgado, Laura. "ULA's Tory Bruno Vows To Transform Company." Space Policy Online. November 14, 2014. Accessed September 10, 2018. https://spacepolicyonline.com/news/ulas-tory-bruno-vows-to-transform-company/.

6 Ibid.

7 Chaikin, Andrew. "Is SpaceX Changing the Rocket Equation?" Air & Space Magazine. January 01, 2012. Accessed September 10, 2018. https://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation

8 Ibid.

not publicly known how much extra money the government provided. However, given the expendable and high-quality nature of the rockets, making them expensive to produce, and the state of the market for defense contracts—monopoly with a cost-plus system—it can be inferred that ULA had high profit margins. This is supported by the fact that, in 2014, Lockheed Martin, a 50% stakeholder in ULA, reported that ULA's earnings had increased by 29%, and were responsible for increasing the profit margins of Lockheed Martin to 13.6% from 13.2%[9]. Because ULA's prices were inflated and allocative efficiency is achieved where the price of a good equals the marginal cost of production, the U.S. launch vehicle market was not allocatively efficient at this time. Furthermore, because ULA had no incentive to minimize the cost of its rockets, it is likely that it was not producing at a level which minimized its ATC, meaning that the market was not productively efficient.

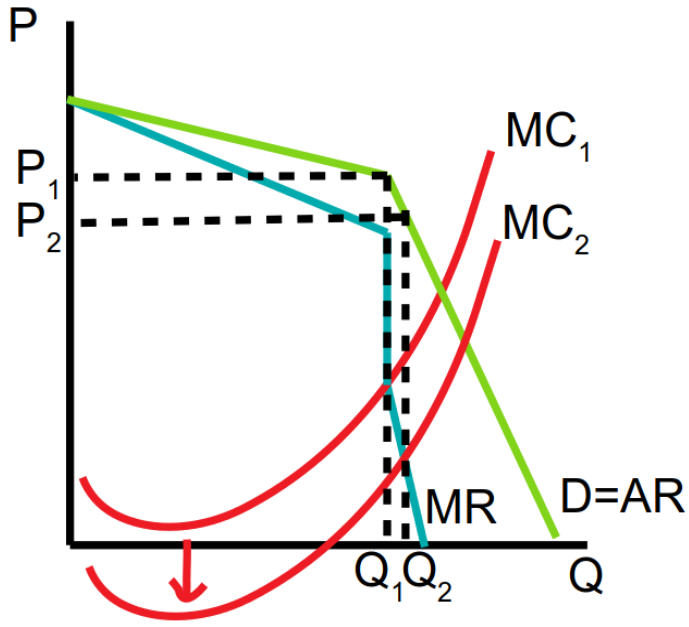
The lack of allocative efficiency was exacerbated by the significant information asymmetry present between the Department of Defense (the DoD, one of ULA's main customers) and ULA. As stated in a report by the Government Accountability Office, "The ELC [EELV Launch Capability] cost-reimbursement contract was not transparent…minimal insight into contractor cost or pricing data meant DOD may have lacked sufficient knowledge to negotiate fair and reasonable launch prices."[10] This suggests that the "ELC cost-reimbursement contracts" (cost-plus contracts) were negotiated with information asymmetry favouring ULA, which decreased the allocative efficiency of the market because it allowed ULA to sell launch vehicles at prices much higher than the marginal cost of production.

9 De Selding, Peter B. "ULA Earnings Take Some of the Sting out of Lockheed's Lackluster Space Returns." SpaceNews. December 16, 2014. Accessed October 14, 2018. https://spacenews.com/42282ula-earnings-take-some-of-the-sting-out-of-lockheeds-lackluster-space/.

10 "The Air Force's Evolved Expendable Launch Vehicle Competitive Procurement." U.S. Government Accountability Office. March 4, 2014. Accessed September 10, 2018. https://www.gao.gov/assets/670/661330.pdf.

Using the historical rocket launch data[11], which holds that ULA, Orbital Sciences, and SpaceX performed 11, 5, and 3 launches in 2013, respectively, the concentration ratio CR_1 of the market in 2013 can be calculated as 0.58. This would suggest that ULA was a near-monopolist at this time. The fact that CR_4 and even CR_3 were both equal to 1 in 2013 suggests that, if not a monopoly, the industry was definitely an oligopoly. As no evidence of collusion has surfaced, it can be assumed that the oligopoly was non-collusive. In that case, the Price-Quantity diagram of a firm in the market is as follows:

Fig. E, Firm in Launch Vehicle Market in 2013



This kinked demand curve diagram reinforces the idea that the main competition between the LSPs at this time was in the form of product differentiation. Because of the profit maximization rule, firms produce at a quantity where MC=MR. As best explained via game theory, the prices in an oligopoly are sticky upwards and slippery downwards. Hence, firms were discouraged from decreasing their marginal cost below the vertical section of the curve, as a decrease in the company's selling price from P_1 to P_2 would only lead to a small increase in quantity produced from Q_1 to Q_2 and only a slight increase in economic profit. This, in 2013, led to little incentive for firms to decrease prices, and forced them to compete through non-price means, such as reputation and the required approval to serve government contracts.

11 McDowell, Jonathan. *Launchlog*. Txt. August 2018. http://planet4589.org/space/log/launchlog.txt

Changes from 2013 to 2018

The Decline of Cost-Plus

A NASA report which outlined NASA's strategy for cost reduction within 2013-2018 stated that "NASA plans to award competitive, pre-negotiated, milestone-based agreements that support the development, testing, and demonstration of multiple commercial crew systems with a fixed Government investment"[12]. According to another NASA report, this program, with its milestones, "builds in an automatic incentive for companies to complete the effort on or under cost…because of our strategy to invest in multiple companies. This engages the engine of competition where companies strive to offer the best value and capture a share of existing markets or create new markets as soon as possible"[13]. With this theory in mind, NASA awarded milestone-based contracts worth a maximum of 4.2 billion dollars to Boeing (a 50% stakeholder in ULA) and 2.6 billion dollars to SpaceX in 2014[14]. These new contracts, because of their large awards, also decreased barriers to entry into the market. The transition from a cost-plus contract model to a milestone-based contract model has been one of the leading factors in creating a more competitive market, as it has incentivized the entry of new companies and allowed growing companies like SpaceX to rapidly expand productive resources. Furthermore, it has increased the allocative efficiency by limiting information asymmetry—a market failure—and by forcing companies to decrease prices. Moreover, the competition, as discussed in the Economic Theory section, increased productive efficiency.

12 "Commercial Market Assessment for Crew and Cargo Systems." National Aeronautics and Space Administration. April 27, 2011. Accessed September 10, 2018. https://www.nasa.gov/sites/default/files/files/Section403(b)CommercialMarketAssessmentReportFinal.pdf.

13 "Commercial Orbital Transportation Services." National Aeronautics and Space Administration. February, 2014. Accessed September 10, 2018. https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf.

14 Beutel, Allard. "NASA Chooses American Companies to Transport U.S. Astronauts to Intern." National Aeronautics and Space Administration. September 16, 2014. Accessed September 10, 2018. https://www.nasa.gov/press/2014/september/nasa-chooses-american-companies-to-transport-us-astronauts-to-international.

Because high entry barriers are one of the main characteristics of a Monopoly or Oligopoly market structure, the transition to a milestone-based contract system signified a transition to a less oligopolistic market. This is evidenced by the appearance of a new competitor in the U.S. launch vehicle market in this time period: Rocket Lab. However, they only received minimal funding from the US government: $6.95 million from NASA[15] and $99,964 from DARPA, both in 2015[16]. This shows that the market's barriers to entry have decreased sufficiently to allow new competitors to enter, even without significant government intervention. This is again indicative of a shift to a less oligopolistic market structure, which, as discussed earlier, leads to more productive and allocative efficiency.

However, this does not mean that cost-plus contracts disappeared. Orbital Sciences, which was one of the original oligopolists in 2013 and later became known as Orbital ATK, received 52% of its government revenue in 2013 from "cost-reimbursable" (AKA cost-plus) contracts[17]. In 2017, it received 36% of its government revenue from such contracts[18]. While cost-plus contracts remained in use, their share declined in favour of milestone-based contracts.

15 "Rocket Lab Wins $6.95M NASA Launch Contract." Rocket Lab. October 31, 2015. Accessed September 09, 2018. https://www.rocketlabusa.com/news/updates/rocket-lab-wins-6-95m-nasa-launch-contract/.

16 Messier, Doug. "DARPA SBIR Awards for XS-1 & Rocket Technologies." Parabolic Arc. March 30, 2016. Accessed September 09, 2018. http://www.parabolicarc.com/2016/03/30/darpa-sbir-awards-xs1-rocket-technologies/.

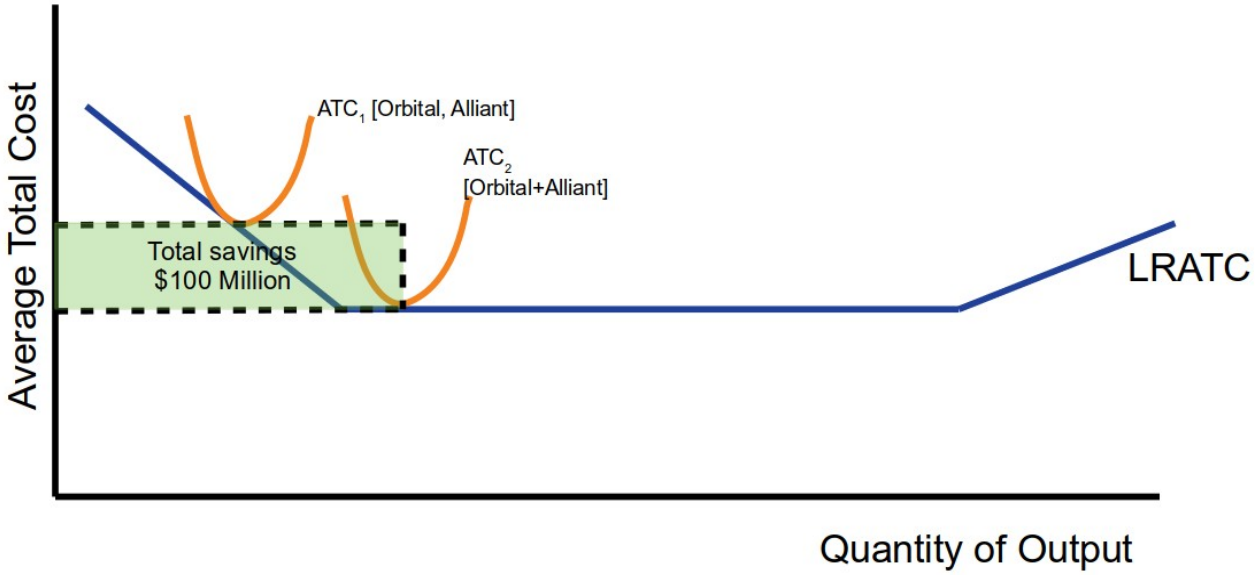
17 Thompson, David W. "ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934 For the fiscal year ended December 31, 2013." U.S. Securities and Exchange Commission. February 24, 2014. Accessed September 09, 2018. https://www.sec.gov/Archives/edgar/data/820736/000082073614000017/form_10-k.htm.

18 Thompson, David W. "ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934 For the fiscal year ended December 31, 2017." U.S. Securities and Exchange Commission. February 21, 2018. Accessed September 09, 2018. https://www.sec.gov/Archives/edgar/data/866121/000086612118000014/oa-1231201710xk.htm.

Economies of Scale & Vertical Integration

This time period saw many companies seeking to take advantage of economies of scale to become more efficient to stay competitive. For example, in 2015, Orbital Sciences Corporation and the aerospace group of Alliant Techsystems merged. Both were in the launch vehicle industry, but large proportions of their products lay outside of the launch vehicle market. Orbital produced launch vehicles, satellites, resupply spacecraft, and various national defense products, while Alliant Techsystems produced engines, launch vehicles (though none were actually launched in this time period), and various national defense products. In fact, many of the engines used on Orbital's rockets were produced by Alliant Techsystems. Their merger was the natural result of their overlapping products, potential for vertical integration, and economies of scale.

Fig. F: Economies of Scale



The merger of the companies allowed them to "streamline operations", and, as reflected in the Fig. F, was expected to yield total savings of "up to $100 million", though no information on actual savings is available[19]. There are several reasons why economies of scale could be realized in this case. As their products overlapped, the new company, Orbital ATK, would i) eliminate spending on redundant R&D, ii) reduce the number of executives, iii) economize through bulk purchasing, iv) pay lower interest on capital, and v) eliminate redundant infrastructure, such as launch facilities and satellite communication infrastructure. Diagrammatically, the ATC curves of Orbital and Alliant can be represented at ATC_1 in Fig. D when they are separate. When they merged, their total output increased such that their combined ATC could now be represented at ATC_2. It is therefore evident how their merger decreased their ATC through increasing returns to scale along the Long-Run Average Total Cost curve. Given that Orbital Sciences, at the time, still received many cost-plus contracts, the fact that this merger occurred suggests that there were market pressures at play other than the decline of cost-plus.

19 Jayakumar, Amrita. "ATK to merge with Orbital Sciences in $5 billion deal, spin off sports division." The Washington post. April 29, 2014. Accessed October 26, 2018. https://www.washingtonpost.com/business/capitalbusiness/atk-to-merge-with-orbital-sciences-in-5-billion-deal-spin-off-sports-division/2014/04/29/59dba21a-cfb3-11e3-a6b1-45c4dffb85a6_story.html

Under very competitive circumstances, such a merger would increase productive efficiency, because the two firms, when combined, could better utilize their productive resources. However, as there were very few competitors in the US launch vehicle market, this merger significantly decreased competition, gave the firm a larger market share, and enabled it to act as more of a price-setter. Therefore, as discussed in the Economic Theory section, this decrease in competition could have overall decreased both productive and allocative efficiency.

In June 2018, Northrop Grumman completed a merger with OrbitalATK. Northrop Grumman is a company which, in the aerospace sector, produces various military satellite payloads. Because OrbitalATK was, in contrast, a launch vehicle company, this was clearly an attempt at vertical integration. Although no quantitative data is available, some productive efficiency, due to economies of scale and the efficiency of vertical integration, has most likely been achieved by limiting redundancy in production facilities, testing facilities, and management. As stated in the acquisition press release by the chairman of Northrop Grumman, “Our complementary portfolios…will yield significant value creation through revenue synergies associated with new opportunities, cost savings…”[20]. Regarding the "new opportunities", it is possible that, due to being a part of Northrop Grumman, a major defense contractor, OrbitalATK rockets will get certified for defense contracts, further decreasing the amount of product differentiation within the market, and thereby decreasing ULA's market share. This would shift the market to a more competitive market structure and, as shown in the Economic Theory section, make the launch vehicle market more productively and allocatively efficient.

20 "Northrop Grumman to Acquire Orbital ATK for $9.2 Billion." Northrop Grumman. September 18, 2017. Accessed September 10, 2018. http://investor.northropgrumman.com/news-releases/news-release-details/northrop-grumman-acquire-orbital-atk-92-billion-1.

Restructuring of companies

ULA had a monopoly on defense launch contracts in 2013, but they soon began losing their monopoly position. SpaceX filed a complaint against the United States Air Force (USAF) in April of 2014 for giving ULA a five-year $11 billion sole-source contract, arguing that SpaceX could do it for cheaper[21]. The USAF began certifying SpaceX for launches, and ULA expected the certification of SpaceX to complete by June 2015[22]. As this certification would increase competition and bring an end part of ULA's product differentiation capability, ULA CEO Tony Bruno stated that he wanted to restructure the company to decrease costs and attract more commercial customers[23]. However, it must be noted that there were other reasons for ULA's restructuring. Due to the geopolitical situation at the time, the United States Federal Government passed a law that would, in national security launches, prohibit the use of the Russian rocket engines used in ULA's Atlas 5 launch vehicles. Furthermore, not only would there be more competition for the defense contracts, but ULA expected that the total number of defense contracts available would decrease[24]. Thus it cannot be stated that the increased competition was all that led to ULA's restructuring.

As part of a transformation to reduce the cost and process time of launches, ULA announced a restructuring and conducted several rounds of downsizing:

1. In December of 2015, ULA laid off 12 executives[25], 30% of their total executive team.

21 Delgado, Laura. "ULA's Tory Bruno Vows To Transform Company." Space Policy Online. November 14, 2014. Accessed September 10, 2018. https://spacepolicyonline.com/news/ulas-tory-bruno-vows-to-transform-company/.

22 Shalal, Andrea. "Lockheed-Boeing rocket venture needs commercial orders to survive." Reuters. May 21, 2015. Accessed September 10, 2018. https://www.reuters.com/article/us-lockheed-martin-boeing-ula/lockheed-boeing-rocket-venture-needs-commercial-orders-to-survive-idUSKBN0O62M720150521.

23 Delgado, Laura. "ULA's Tory Bruno Vows To Transform Company." Space Policy Online. November 14, 2014. Accessed September 10, 2018. https://spacepolicyonline.com/news/ulas-tory-bruno-vows-to-transform-company/.

24 Shalal, Andrea. "Lockheed-Boeing rocket venture needs commercial orders to survive." Reuters. May 21, 2015. Accessed September 10, 2018. https://www.reuters.com/article/us-lockheed-martin-boeing-ula/lockheed-boeing-rocket-venture-needs-commercial-orders-to-survive-idUSKBN0O62M720150521.

25 Shalal, Andrea. "Exclusive: Lockheed-Boeing venture lays off 12 executives in major reorganization." Reuters. May 14, 2015. Accessed October 29, 2018. https://www.reuters.com/article/us-lockheed-boeing-ula/exclusive-lockheed-boeing-venture-lays-off-12-executives-in-major-reorganization-idUSKBN0O029D20150515.

2. In 2016, ULA laid off 350 workers[26].
3. In 2017, ULA laid off 400-500 workers, or at least planned to (data on how many workers were actually laid off is not available). This was a quarter of its workforce[27].

Official information on how the company actually internally restructured, and not just downsized, to increase efficiency is not available. However, some restructuring can be seen in the second layoff, which primarily affected ULA's workers at Vandenberg Air Force Base, ULA's West Coast launch facility. In order to streamline the company and limit redundancy in the workforce, ULA workers on the East Coast would travel to Vandenberg to perform launches[28].

All of this evidences ULA's trend of restructuring to increase efficiency in the time period of 2013-2018. ULA decreased variable costs by laying off workers, and decreased fixed costs by laying off executives. In the future, ULA plans to further decrease fixed costs by reducing their number of launch pads to two[29].

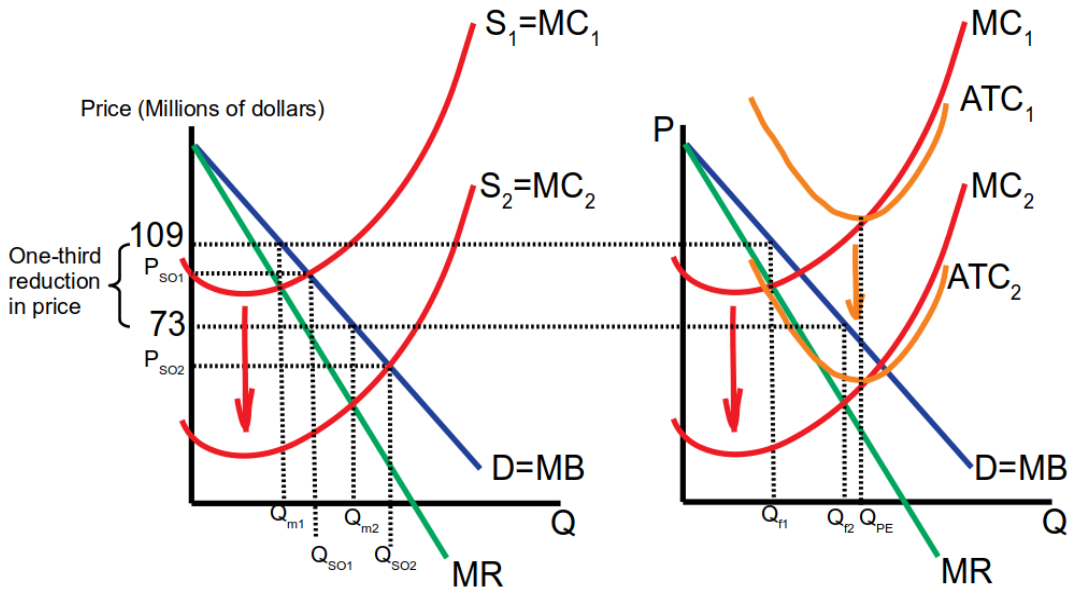
26 Cook, Tracy M. "87 people laid off from United Launch Alliance in Colorado as company shrinks to compete." The Denver Post. June 30, 2016. Accessed September 10, 2018. https://www.denverpost.com/2016/06/30/united-launch-alliance-colorado-layoffs/.

27 Klotz, Irene. "United Launch Alliance to lay off up to 875 by end of 2017: CEO." Reuters. April 14, 2016. Accessed September 10, 2018. https://www.reuters.com/article/us-space-ula-layoffs-idUSKCN0XB2HQ.

28 Murray, Scott. "BREAKING: Layoffs Imminent At United Launch Alliance." Space News 360. March 2, 2017. Accessed October 29, 2018. https://spacenews360.com/breaking-layoffs-imminent-united-launch-alliance/.

29 Butler, Amy. "New Rocket, White Tails In ULA’s Long-Term Strategy." Aviation Week. February 17, 2015. Accessed September 10, 2018. http://aviationweek.com/defense/new-rocket-white-tails-ula-s-long-term-strategy-0.

Figure G, Launch Vehicle Market from 2013-2018 **Figure H, ULA from 2013-208**



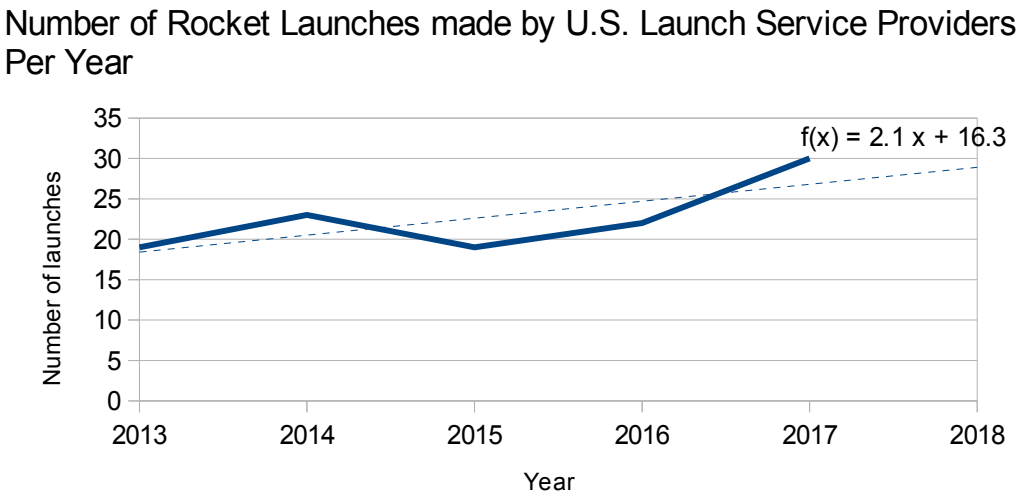
Figures G and H represent the launch vehicle market and ULA, respectively. The arrows represent the change from 2013 to 2018. While the figures assume a monopolistic market, they are still effective in representing productive and allocative efficiency.

Through the decreases in Average Variable Cost and Average Fixed Cost, ULA's MC and ATC decreased, as reflected the shifts from MC_1 to MC_2 and ATC_1 to ATC_2 in Fig. H. It is not known exactly how much ULA decreased its ATC and MC, but decreasing these brought their Atlas V prices down by a third, from $109 million to $73 million[30]. This brought the firm closer to achieving productive efficiency, because production, as determined by the intersection of MC and MR, shifted from a level of output of Q_{f1} to a level of output of Q_{f2}, while the level of output at the minimum of the ATC, Q_{PE} stayed constant. There was no effect on the allocative efficiency, as, in Fig. E, the new price of the good, $73 million, did not get any closer to the new MC of the good, MC_2. This lack of increased allocative efficiency is also evident in that the quantity produced increased from Q_{m1} to Q_{m2}, while the socially optimal quantity increased equally from Q_{SO1} to Q_{SO2}.

30 Klotz, Irene. "United Launch Alliance cuts Atlas rocket price amid competition." Reuters. April 5, 2017. Accessed October 29, 2018. https://www.reuters.com/article/us-space-ula-idUSKBN17706M.

The expansion of SpaceX and overall increase in launches

In 2013, SpaceX had only three launches. From 2014 to 2017, SpaceX performed 39 launches, or almost 10 launches per year. This is evidence that SpaceX became a major competitor for the already well-established ULA. Its competitiveness increased when it received certification, in 2015, to launch military satellites[31]. ULA's product differentiation advantage was partially nullified, and its total monopoly on defense contracts was ended. ULA could no longer maximize profits through this method of non-price competition, and, as seen earlier, was forced to compete in price competition by cutting down its costs of production and decreasing the prices of its products. Again as seen earlier, this competition and restructuring brought the market closer to productive and allocative efficiency.



By examining the rocket launch data, it can be seen that the number of launches done by U.S Launch Service Providers per year increased in the period of 2014 to 2017. 2017 had 11 more launches when compared to 2013. This increase was not due to an increase in demand, but simply due to an increase in SpaceX's launch vehicle production per year, i.e. an increase in the fulfillment of demand, or a decreased shortage. An increase in the fulfillment of demand means that allocative efficiency improved.

31 Gruss, Mike. "SpaceX Falcon 9 Certified for Military Launches." Space News. May 26, 2015. Accessed September 10, 2018. https://spacenews.com/u-s-air-force-certifies-falcon-9-for-military-launches-2/.

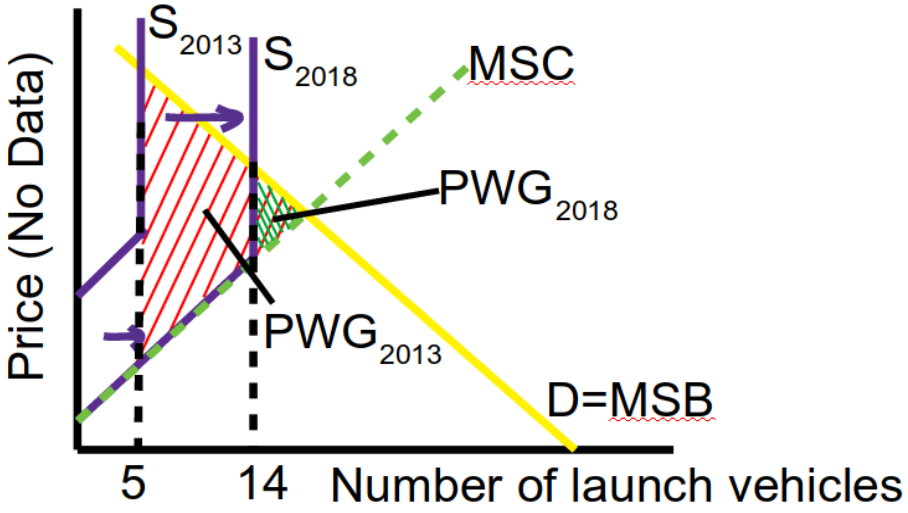
The State of the Market in 2018

According to the aforementioned rocket launch data, as of July 31, ULA, OrbitalATK, SpaceX, and Rocket Lab have conducted 4, 1, 14, and 1 launches, respectively. This puts SpaceX as the leader in a market with a concentration ratio CR_1 of 0.7. This is fairly reminiscent of 2013, when the market had a had a CR_1 of 0.58 with ULA being the main competitor. Contrary to economic theory, SpaceX's dominant position does not necessarily mean that a new inefficiency has emerged. In fact, SpaceX has not yet abused its dominant position, and has continued to decrease prices with a full launch manifest[32]. This suggests that SpaceX is insecure in this position, that there is still significant competition within the U.S. launch vehicle market, and that it is thus more allocatively and productively efficient than in 2013.

32 Baylor, Michael. "With Block 5, SpaceX to increase launch cadence and lower prices." NASA Spaceflight. May 17, 2018. Accessed September 11, 2018. https://www.nasaspaceflight.com/2018/05/block-5-spacex-increase-launch-cadence-lower-prices/

Given that SpaceX has 42 entries in its launch manifest, and managed to perform only 18 launches in 2017[33], it is clear that it still does not produce enough launch vehicles to be socially optimal. SpaceX has simply not been able to expand its productive resources fast enough to meet the high demand for its launch vehicles.

Figure F: Market for SpaceX Launch Vehicles



Though this diagram is limited as SpaceX's launch prices did not decresae significantly, it still accurately shows that SpaceX's supply of launch vehicles (S_{2013} and S_{2018}) becomes perfectly inelastic at a certain point, due to the limitations of its short-run productive resources. Over the long-run, the supply has been increasing (shown in the shift from S_{2013} to S_{2018}), but it is still not enough to meet the demand. The Potential Welfare Gain (PWG) has decreased from PWG_{2013} to PWG_{2018}, showing an increase in allocative efficiency. However, there is still welfare to be gained. This means that the market for SpaceX launch vehicles, and thus the overall US launch vehicle market, is still not allocatively efficient.

33 "Launch Manifest." SpaceX. Accessed September 11, 2018. https://www.spacex.com/missions/.

Conclusion

Though the changes in productive and allocative efficiency are impossible to quantitatively state, it is still clear that several changes in the U.S. launch vehicle market from 2013 to 2018 increased the productive and allocative efficiency of the market, but increased competition was the most significant factor.

In 2013, the market was an oligopoly in which firms competed through non-price competition. The major competitor at the time was ULA, which had a monopoly on a large sector of the market: defense contracts. As a result of the C3PO and its milestone-based contracts, firms were given an incentive to compete by decreasing prices. This decreased barriers to entry and rewarded growth, allowing Rocket Lab to enter the market and SpaceX to increase production. As a result, the total number of launches increased, which minimized deadweight loss by reducing the shortage. These changes increased competition, which forced ULA to restructure and downsize to compete by better utilizing its productive resources, though geopolitical pressures and SpaceX's USAF certification were also factors. The increased competition also made Orbital Sciences seek economies of scale to improve its competitive position through a series of mergers, the net effect of which on efficiency is unclear given the available information. Moreover, the shift to price competition caused by the C3PO represented a shift to a less oligopolistic market, which entailed an increase in productive and allocative efficiency.

The increased competition was kick-started by the C3PO, and this newfound competition, combined with some minor factors, led to a series of changes in the market, the net result of which was an increase in productive and allocative efficiency.

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